The Importance of Resolution for Modeling Global Snow

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NOAA

Why develop high-resolution global coupled models?

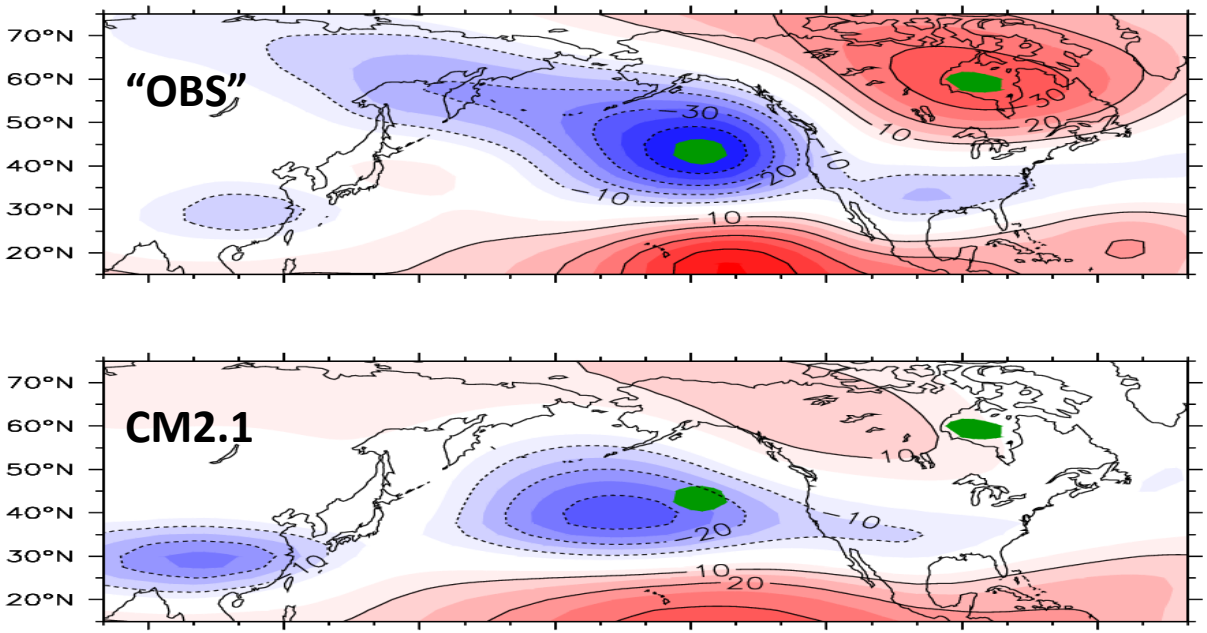
- Improve understanding and prediction of intraseasonal to multidecadal variability
- Improve prediction of transient climate change and role of the ocean in the climate system
- Improve prediction of changes in regional climate, hydrology, and extremes

GFDL Model Characteristics

Detail	CM2.1	CM2.5
Atmospheric Resolution	200km	50km
Atmospheric Vertical Levels	24	32
Oceanic Resolution	100km	28km at the equator to 8-11km at high latitudes

- **Control Simulation:** 280 yrs with 1990 fixed forcings
- **Idealized Climate Change:** 1% increase in CO2 annually until 2xCO2 in year 70, constant thereafter until year 140

Improved Simulation of the Remote Impact of ENSO



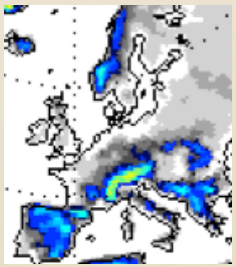
200 hPa DJF geopotential height anomalies regressed onto NINO3 SST

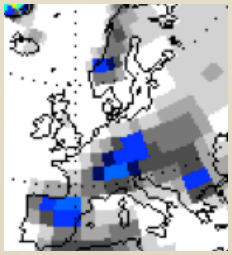
Substantial improvement in simulating remote impact of ENSO

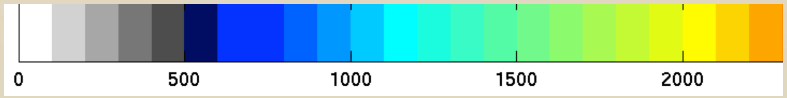
Source: Delworth et al. 2012

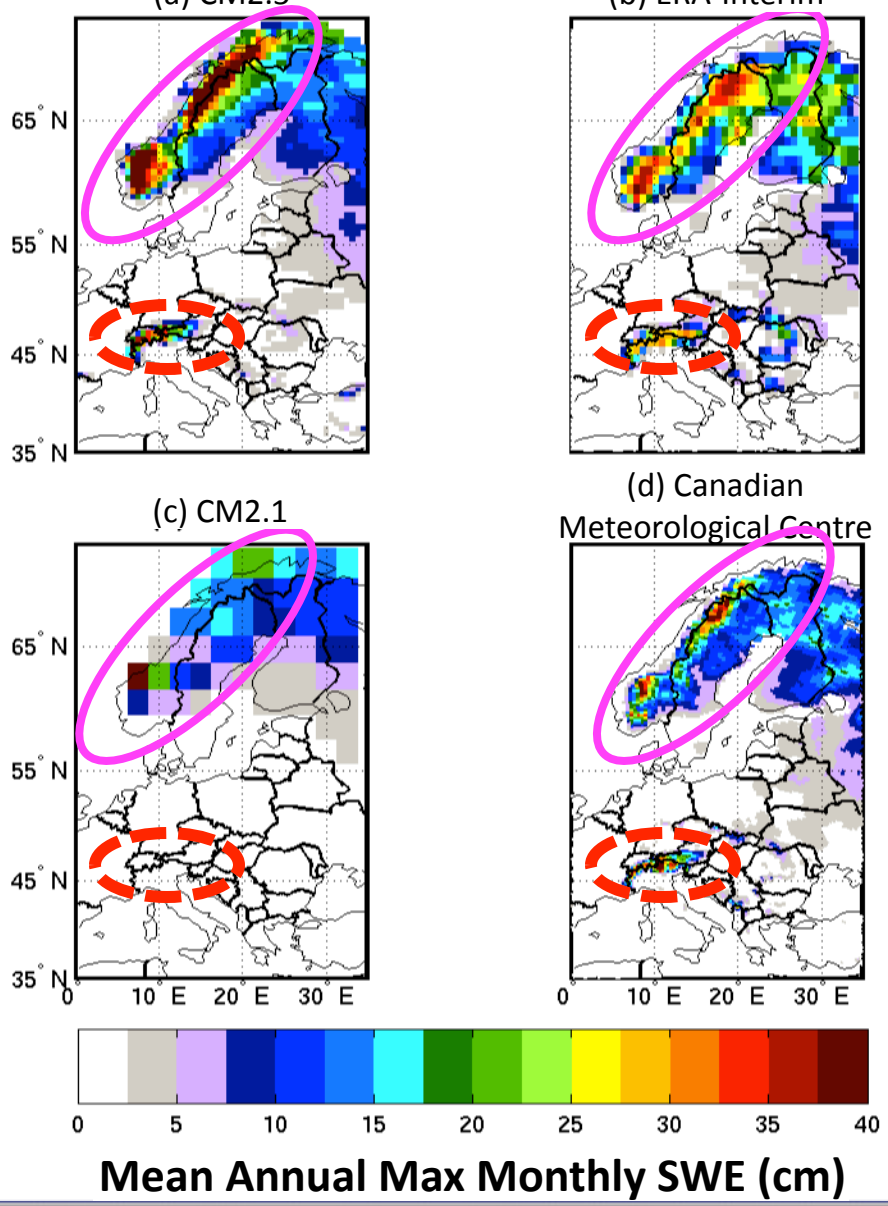
European Snowpack

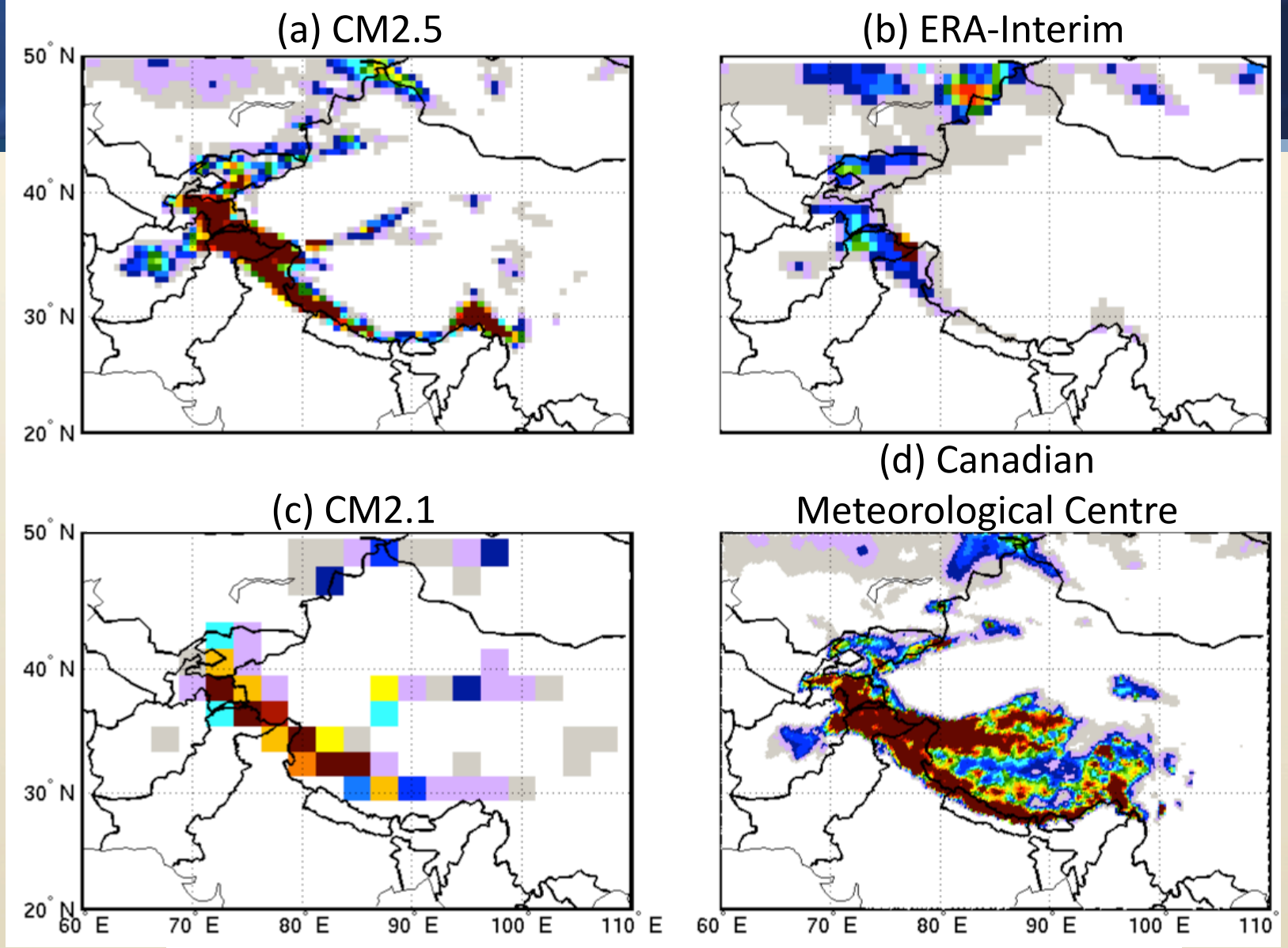
- CM2.5 (a) captures the spatial variability of snowfall in narrow mountain ranges where CM2.1 (c) underperforms
  - → Scandinavia
  - → Alps



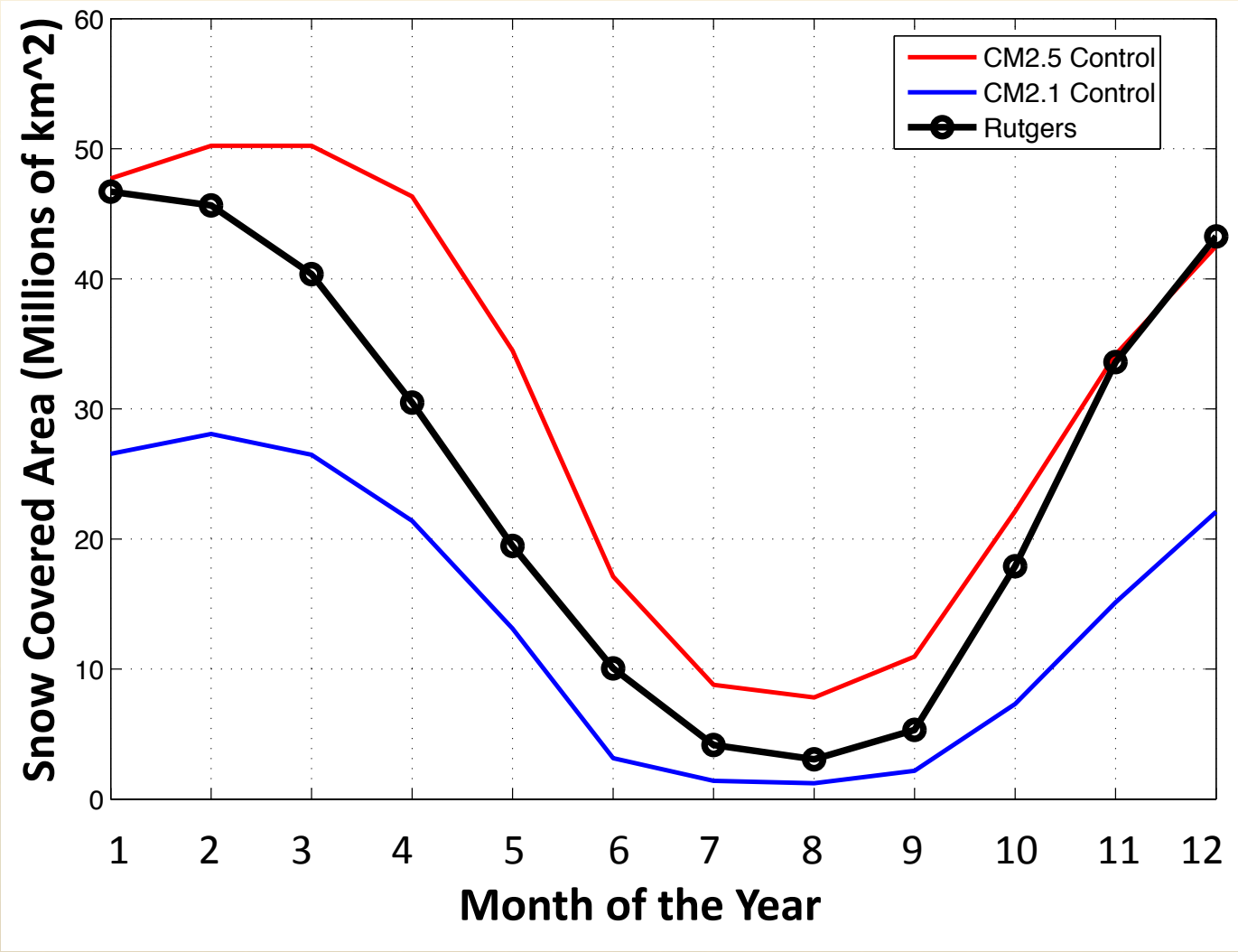




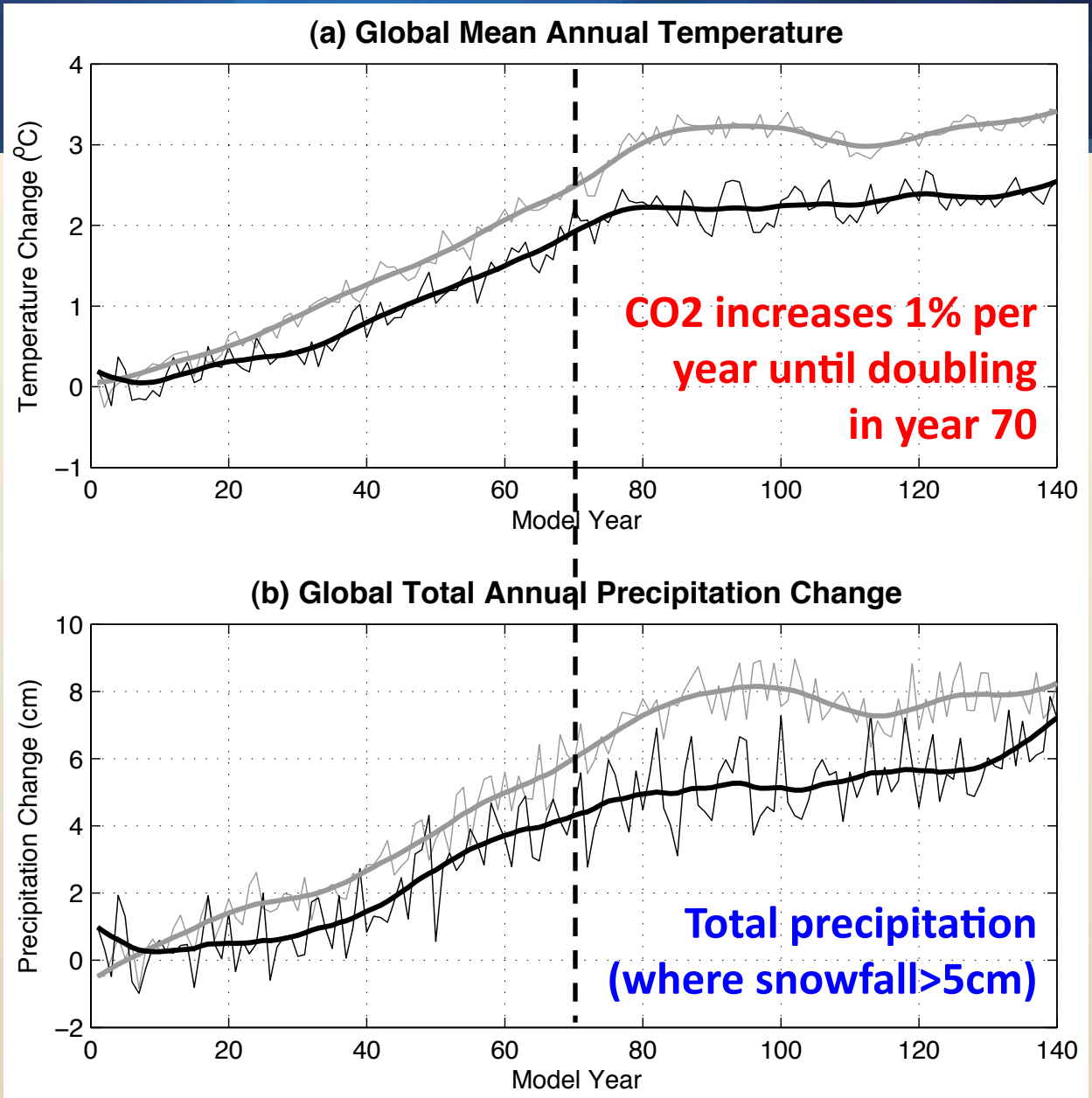



(a) CM2.5
(b) ERA-Interim
(c) CM2.1
(d) Canadian Meteorological Centre
50° N
40° N
30° N
20° N
60° E
70° E
80° E
90° E
100° E
110° E
0
5
10
15
20
25
30
35
40+
Mean Annual Max Monthly SWE (cm)

Seasonal Cycle of N. Hemisphere Snow Covered Area

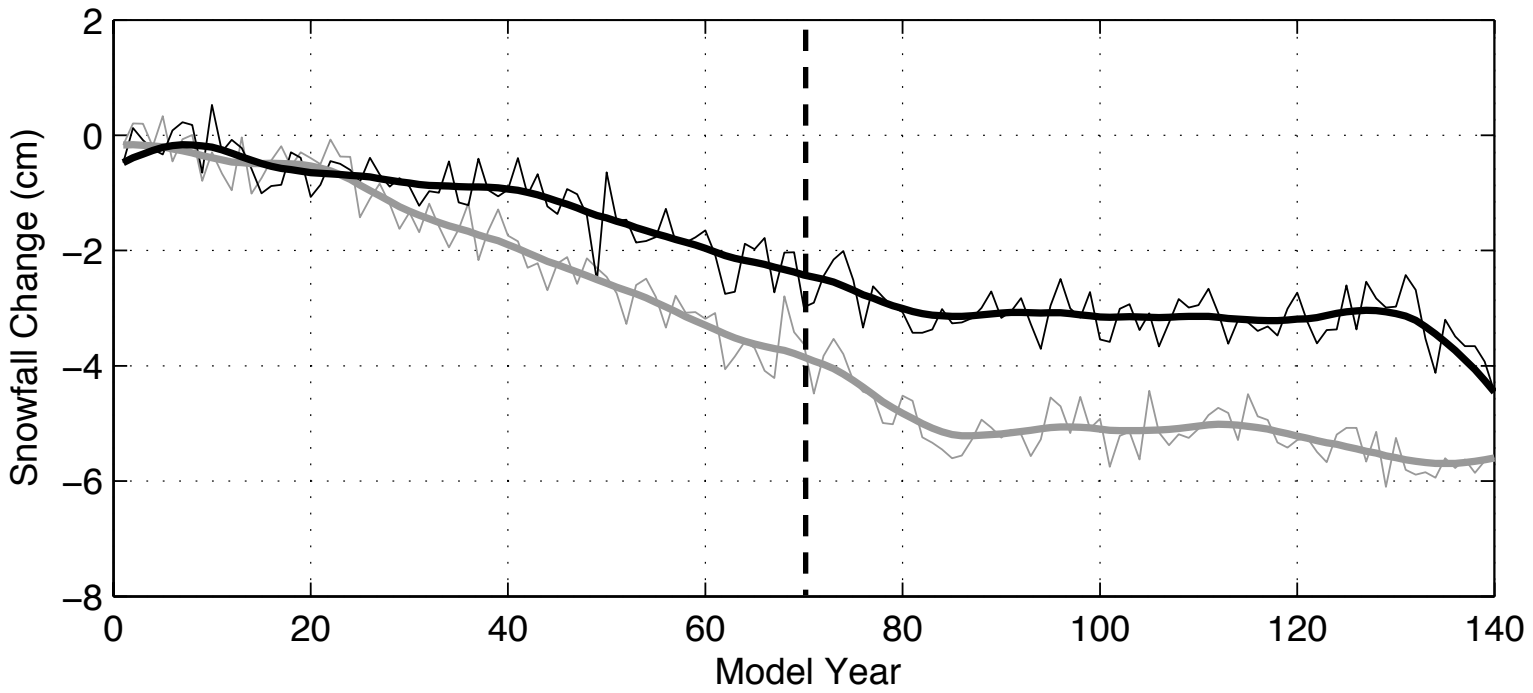


- Minimums are reached in August across all climatologies
- CM2.5 tracks well August-January
- The maximum SCA is reached later in CM2.5
  - Bias source: CM2.5 continues to accumulate snow when Rutgers & CM2.1 show losses



- Temperature **INCREASES** in both models, with a greater increase in CM2.5
- Precipitation **INCREASES** are also greater in CM2.5

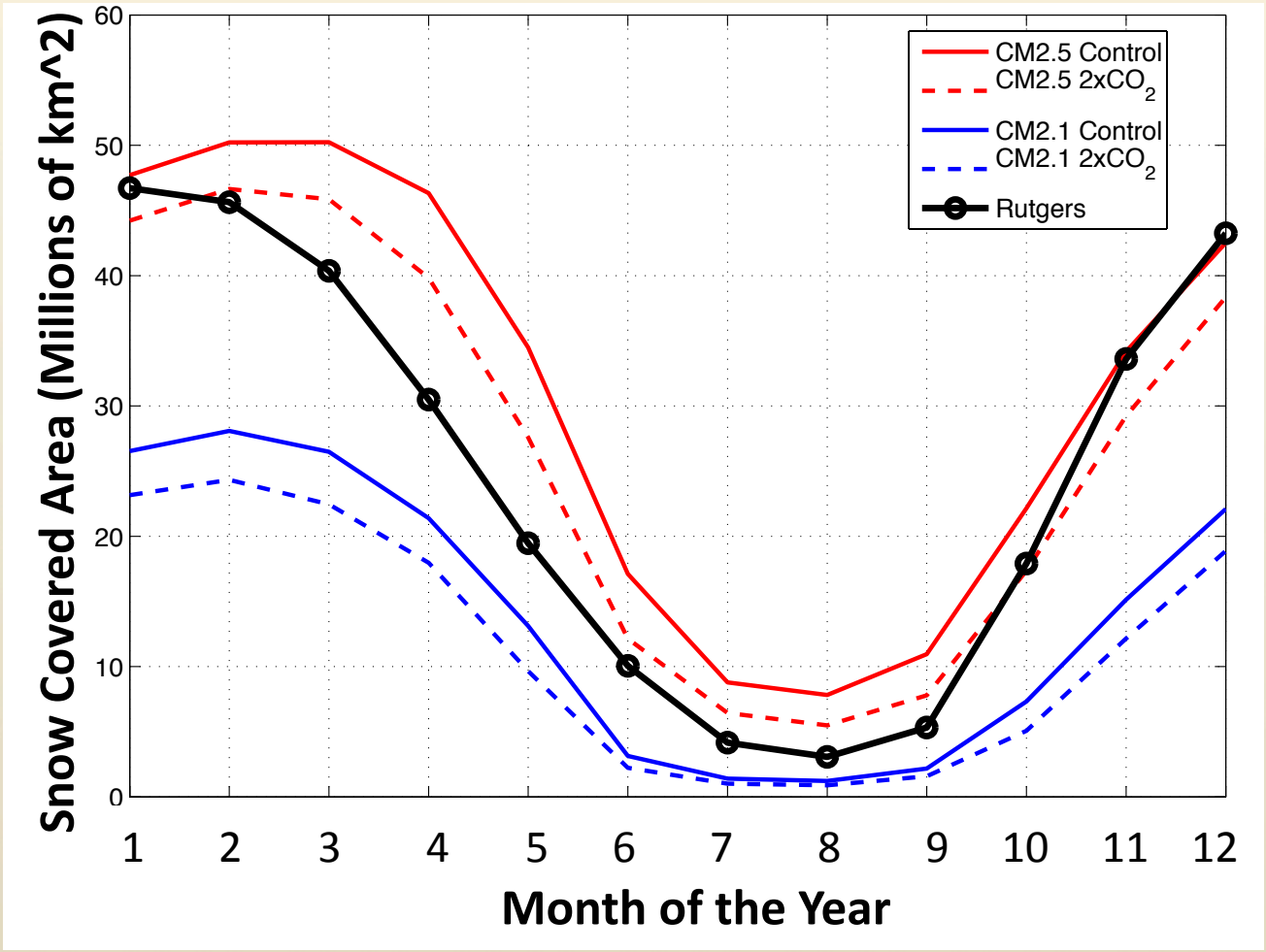
CM2.5 **CM2.1**



CM2.5 **CM2.1**

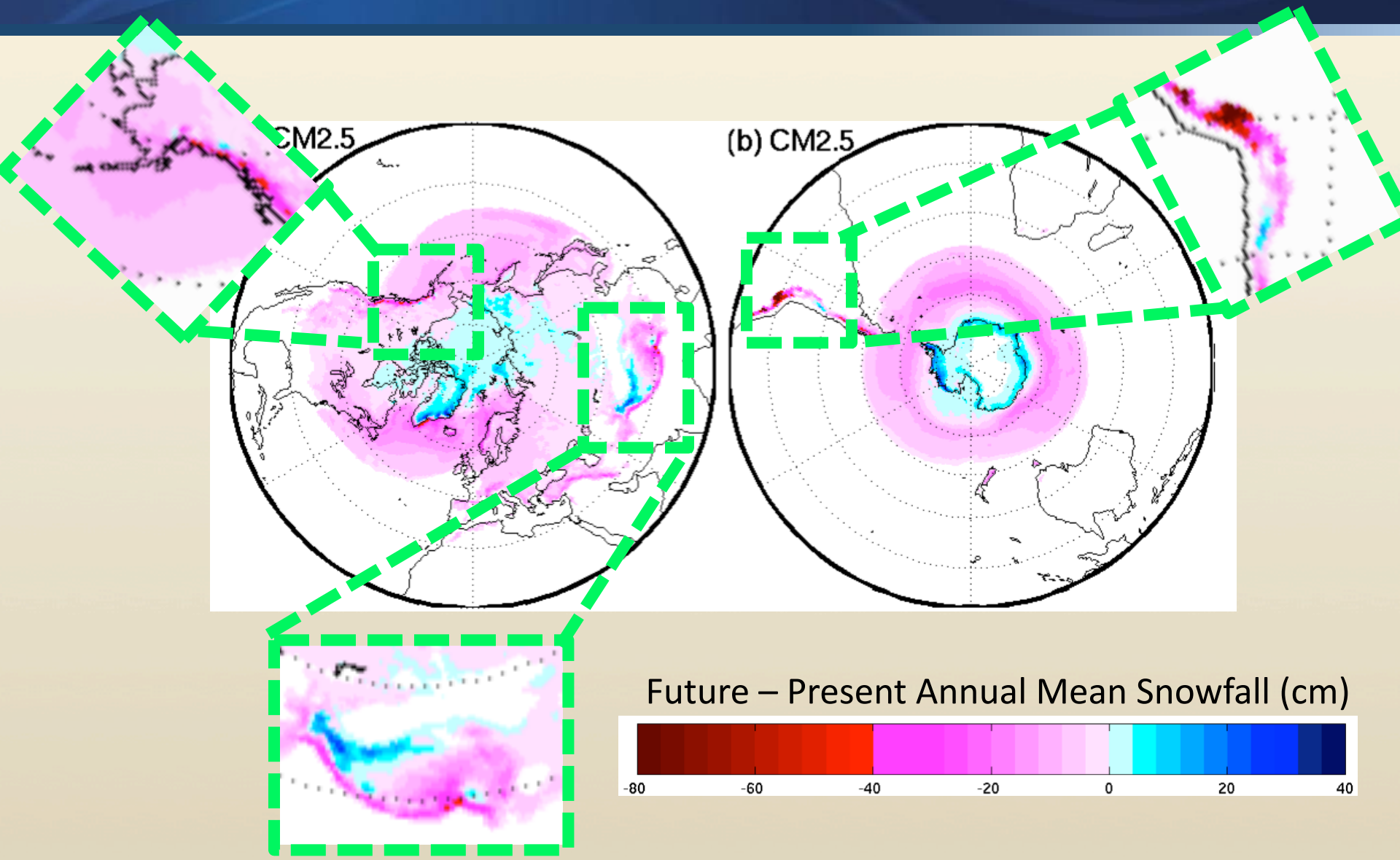
Snowfall **DECREASES** in both models, with a greater loss in CM2.5 DESPITE a greater **INCREASE** in precipitation

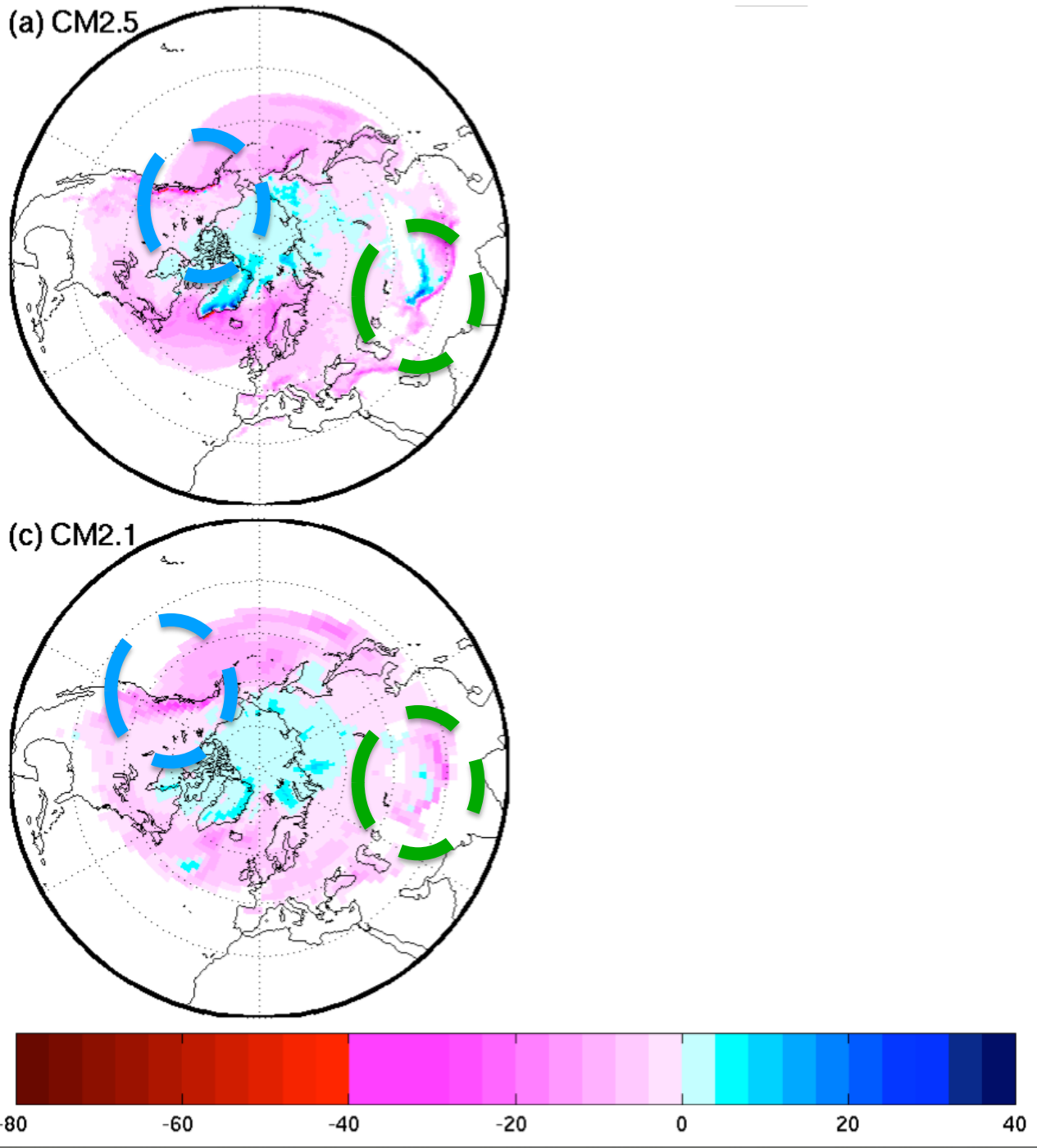
Seasonal Changes: Snow Covered Area



- Snow covered area over the Northern Hemisphere is projected to **decline**
- Reduction magnitude varies over:
  - Season (greatest change in spring)
  - Model

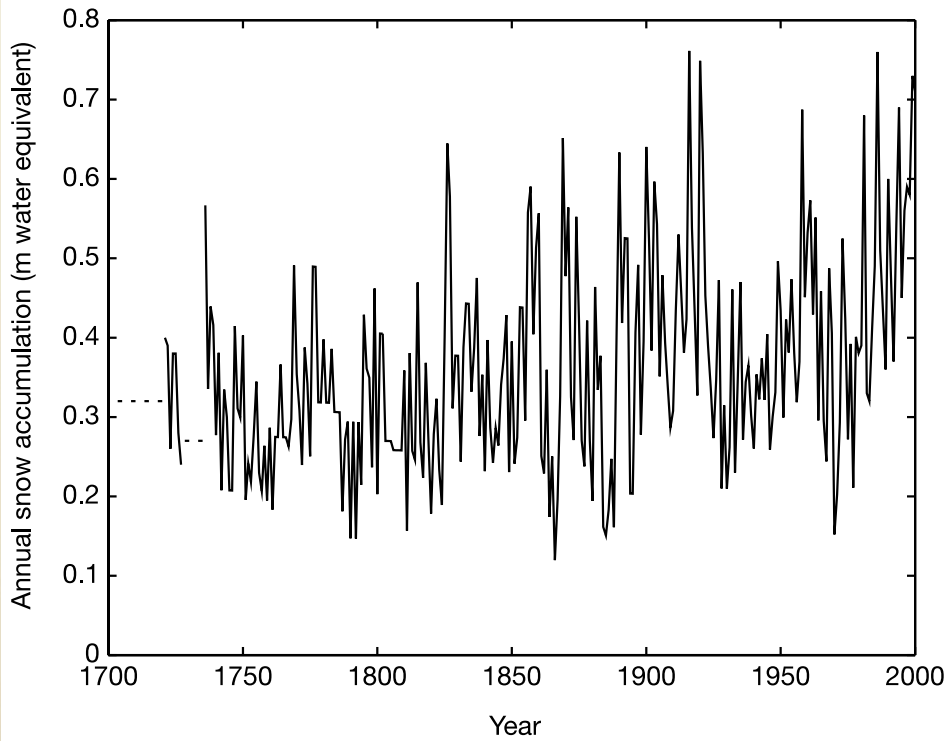
Future Climate: Change In Total Annual Snowfall



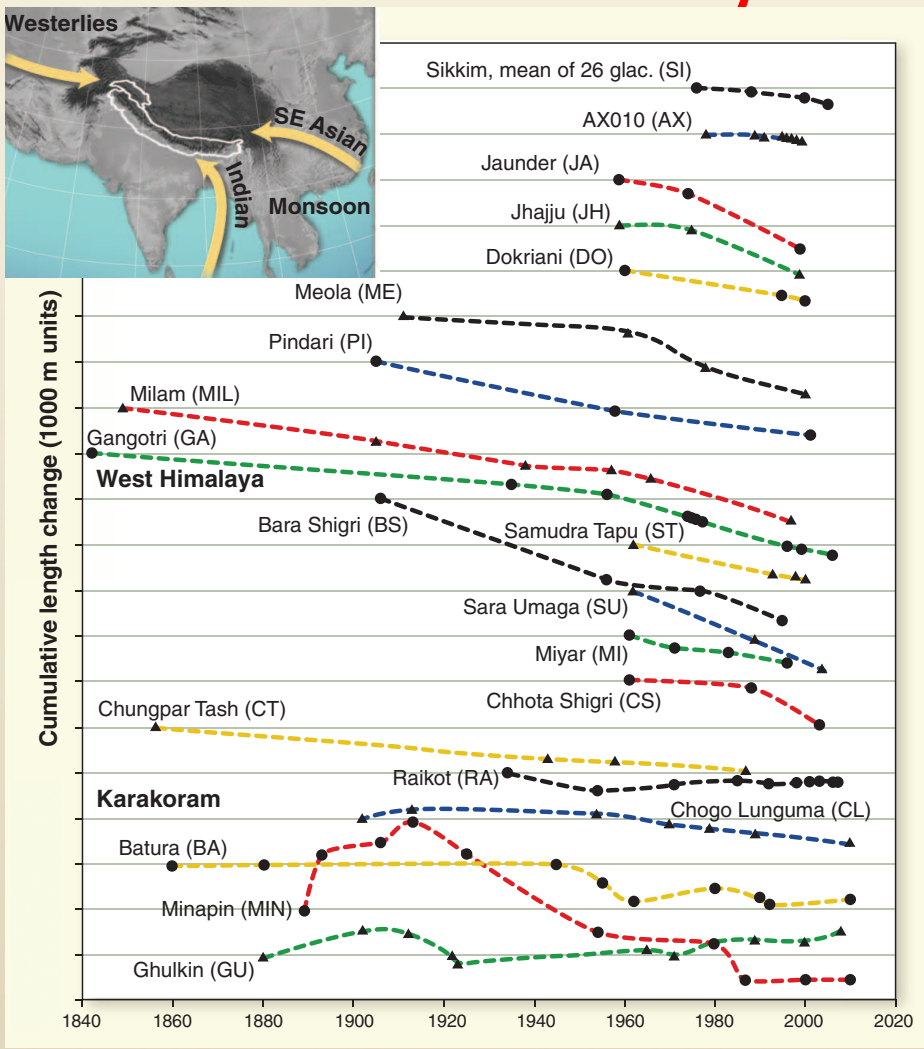

(a) CM2.5
(c) CM2.1
-80
-60
-40
-20
0
20
40

Regions of Observed Positive Snowfall / Glacial Expansion in the Present Climate

Mount Logan (Canada)



Karakoram vs. Himalayas



Sources: Moore et al. 2002, Nature; Bolch et al. 2012, Science

Summary

- The present-climate of snow is better represented by the high resolution model
  - Over complex topography
  - Northern Hemisphere SCA seasonal cycle
- The global and hemisphere averaged values (snowfall and SCA) are uniformly negative under 2xCO2
- High latitude and certain high altitude show increases in snowfall due to the precipitation signal overwhelming influences of temperature
  - The sign of snowfall over complex topography CHANGES from **negative** to **positive** when increasing resolution in a few unique locations